Development/Demonstration of an Advanced Oxy-fuel Fired Front-end System

U.S. Department of Energy

2004 Glass Project Review

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Crystal City, Virginia

Steve Mighton

(740) 321-7633

steve.mighton@owenscorning.com

Presentation Outline

Consortium Membership

Background

- Modeling
- Advantages of oxy flame
- Cost Saving examples

Project Task List

- Bench trials - OC Science & Technology Center, Granville, Ohio
- Ongoing in-plant top fire trial in OC's Guelph
- Side fire trial in Guelph
- Safety interlocks – Jackson no gas, no oxygen

Consortium activity supporting project

Development/Demonstration of an Advanced Oxy-fuel Fired Front-end System

Consortium Partners:

Owens Corning

Osram-Sylvania

BOC

CTI/Eclipse

Objectives:

Develop an oxy-fuel combustion system specifically for front-end systems that delivers:

- Improved energy efficiency
- Reduced operating cost
- Improved environmental performance
- More uniform glass thermal quality.

Development/Demonstration of an Advanced Oxy-fuel Fired Front-end System

Major Tasks:

(1) Develop burner systems for system integration

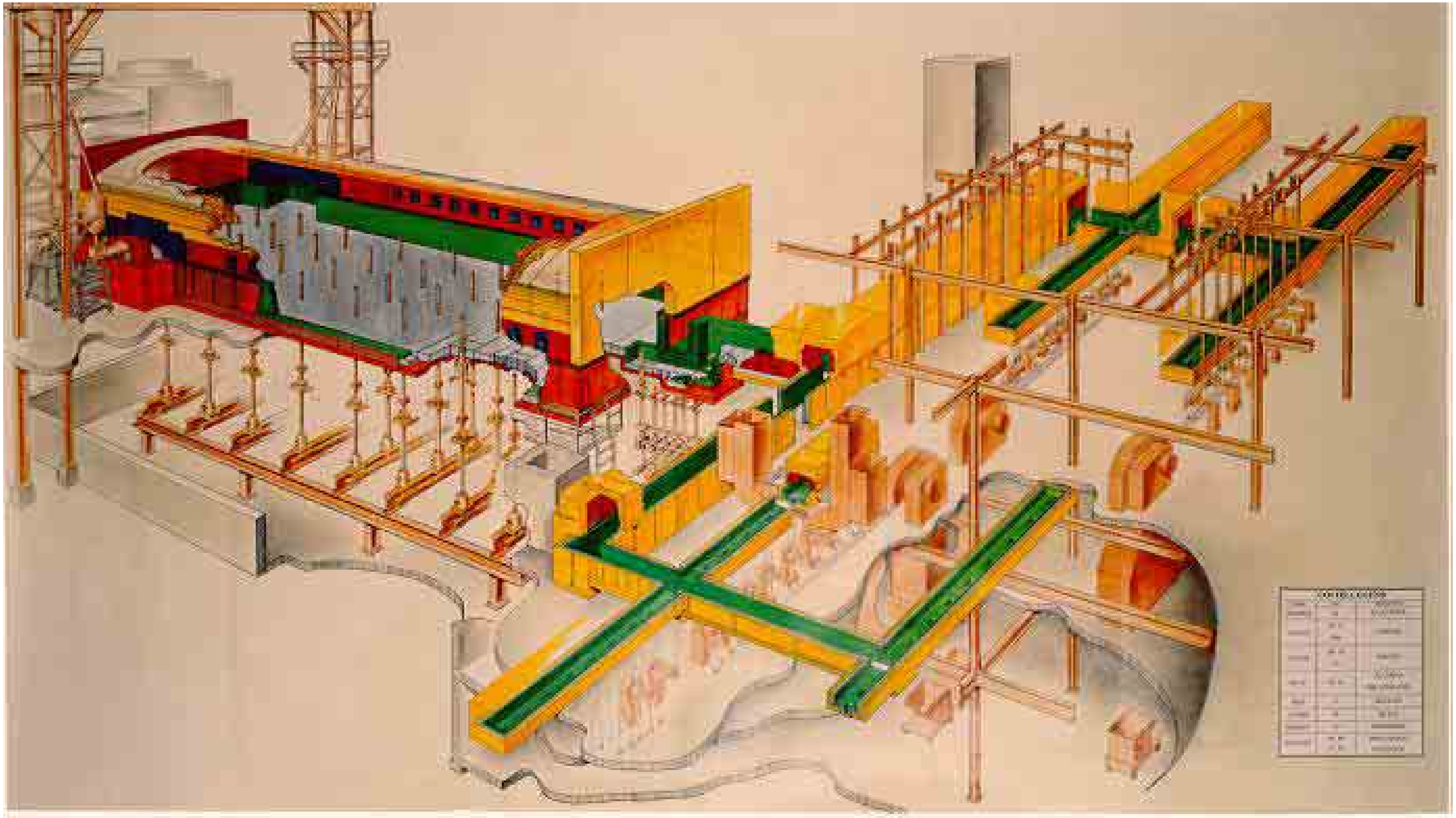
(2) Develop, test a firing system with minimum capital costs

(3) Field test the firing system(s) to obtain operational data;

(4) demonstrate the technology on a production system

(5) work with consortium to benefit other sectors of the glass industry

Development/Demonstration of an Advanced Oxy-fuel Fired Front-end System



Background

- **Energy Usage Distribution in Our Process**

  Oxyfuel Furnace = 47%   Front-end System 53%

- **Current Technology: Low Energy Efficiency = ~25%**

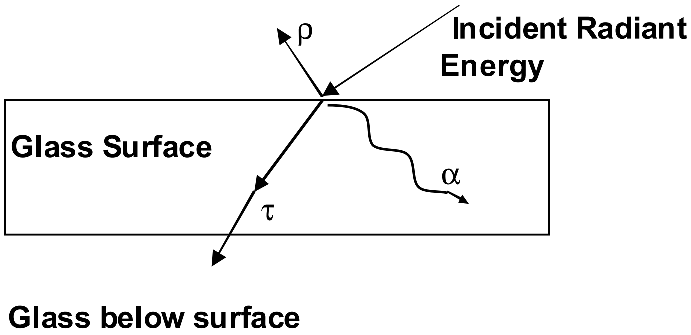
  Massive Piping & Control Systems

- **Prior attempts by the fiberglass industry to use gas/oxy combustion in a Front End have not led significant proliferation due to high cost, long payback or other reasons**
- **Premixed System Always a Safety Concern**

Why oxy firing is more efficient.

Thermal Radiation definitions

- ***Absorptivity***, α, *the fraction of incident energy absorbed by a surface.*
- ***Reflectivity***, ρ, *the fraction of incident energy reflected at a surface.*
- ***Transmisivity***, τ, *the fraction of incident energy <u>transmitted</u> through a surface.*
- ***Emissivity***, ε, *is defined as the fraction of energy emitted by a real surface ratioed to that of an ideal surface.*



Why oxy firing is more efficient

1) Higher flame temperature – more energy radiated due to Δ T

Flame energy radiated (Q) is proportional to the 4th power of the difference in temperature between the flame and glass.

$$\dot{Q} = \varepsilon \cdot \sigma \cdot A\left(T^4_{\text{flame}} - T^4_{\text{glass}}\right)$$

σ = ***constant***

A = surface area

ε = ***thermal emissivity, fraction of energy emitted by flame***

T_{abs} = ***absolute temperature emitting surface***

Why oxy firing is more efficient

1) Higher flame temperature – more energy radiated due to Δ T

$$\dot{Q} = \varepsilon \cdot \sigma \cdot A\left(T^4_{\textbf{flame}} - T^4_{\textbf{glass}}\right)$$

$T_{oxy\ flame}$ = ~ 2973 K (4900 F or 2700 C)

$T_{gas\ flame}$ = ~ 2255 K (3600 F or 2000 C)

T_{glass} = ~ 1643 K (2500 F or 1370 C)

Ratio of (T^4 -T^4) term using: a) **$T_{oxy\ flame}$**

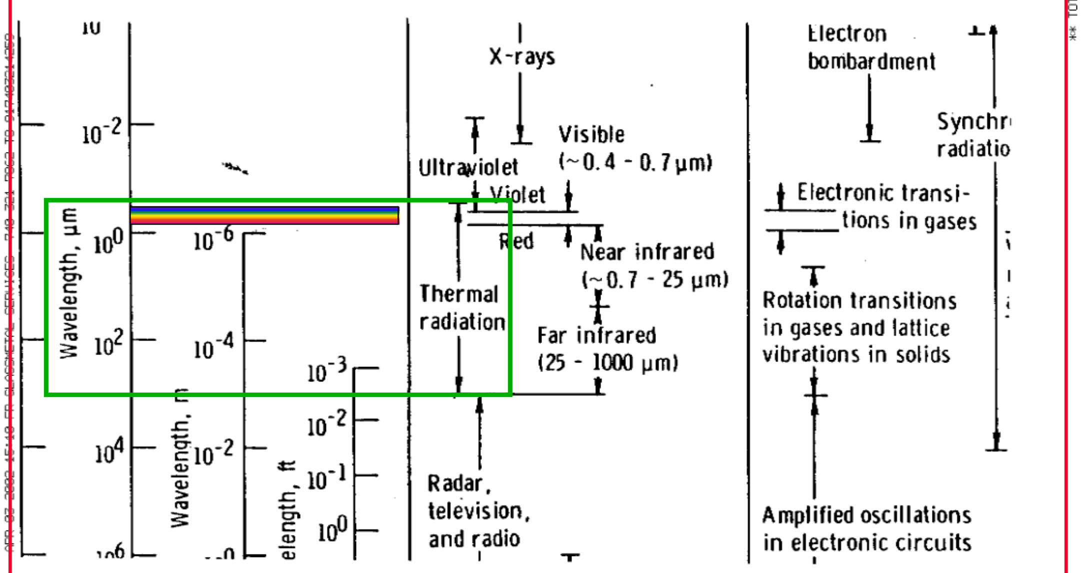
b) **$T_{gas\ flame}$**

Why oxy firing is more efficient

2) Higher flame temperature – more energy **transmitted through** the glass

- Hotter flame has shorter wavelength

Thermal Radiation Bandwidth: 0.2 ~ 1000 micron

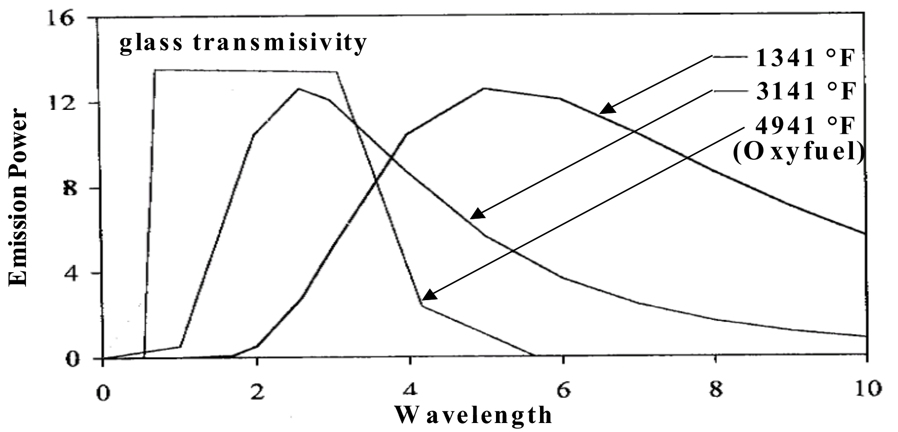


Why oxy firing is more efficient

2) Higher flame temperature – more energy transmitted through the glass

- shorter wavelength radiation enters glass more readily

Spectral Radiation Emission Power



Radiation from combustion can penetrate glass melt.

Why oxy firing is more efficient

3) Oxy/gas flame does not have to heat up N2 in air

- Air is 78% nitrogen, 21% oxygen
- eliminating nitrogen component reduces amount of gas that has to be heated

Why oxy firing is more efficient

Gas savings with oxy firing:

- Melter: ~40% savings
- Front End: ~65-70% energy savings (before oxygen cost)

Why the difference?

Why oxy firing is more efficient

Gas savings with oxy firing:

Melter: ~40% savings

-

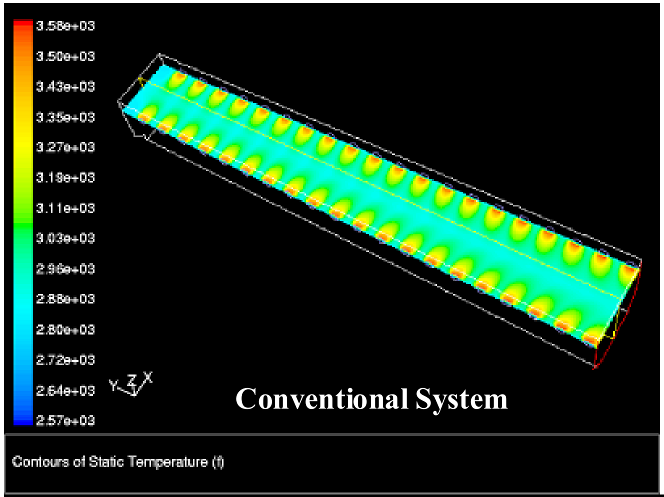
Front End: ~65-70% savings

Why the difference?

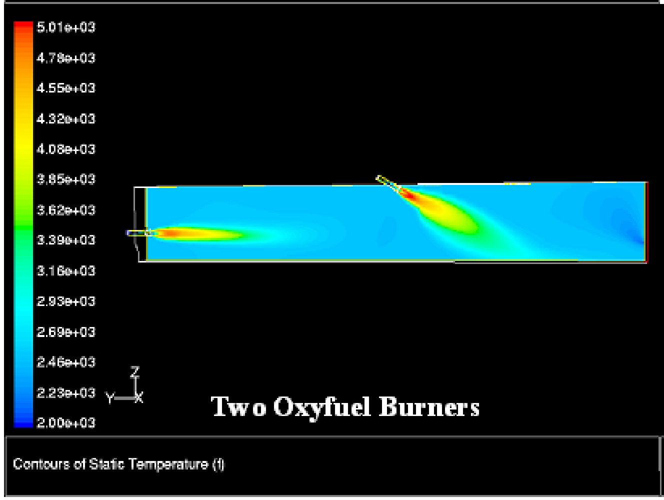
Melter combustion air is preheated in a recuperator

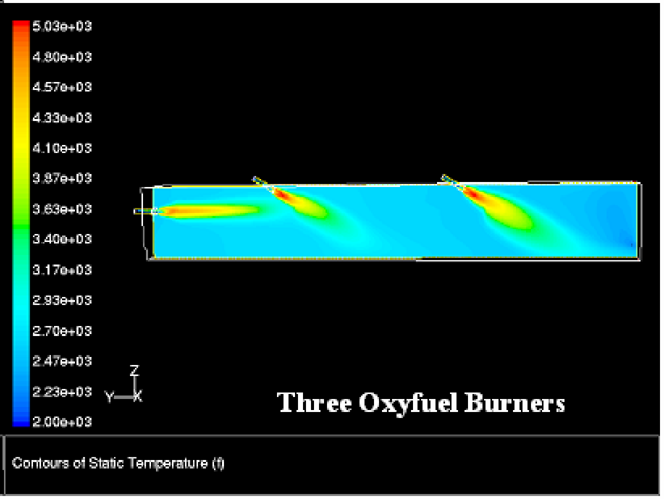
Front End - no recuperator

Technical Approach – The Technology

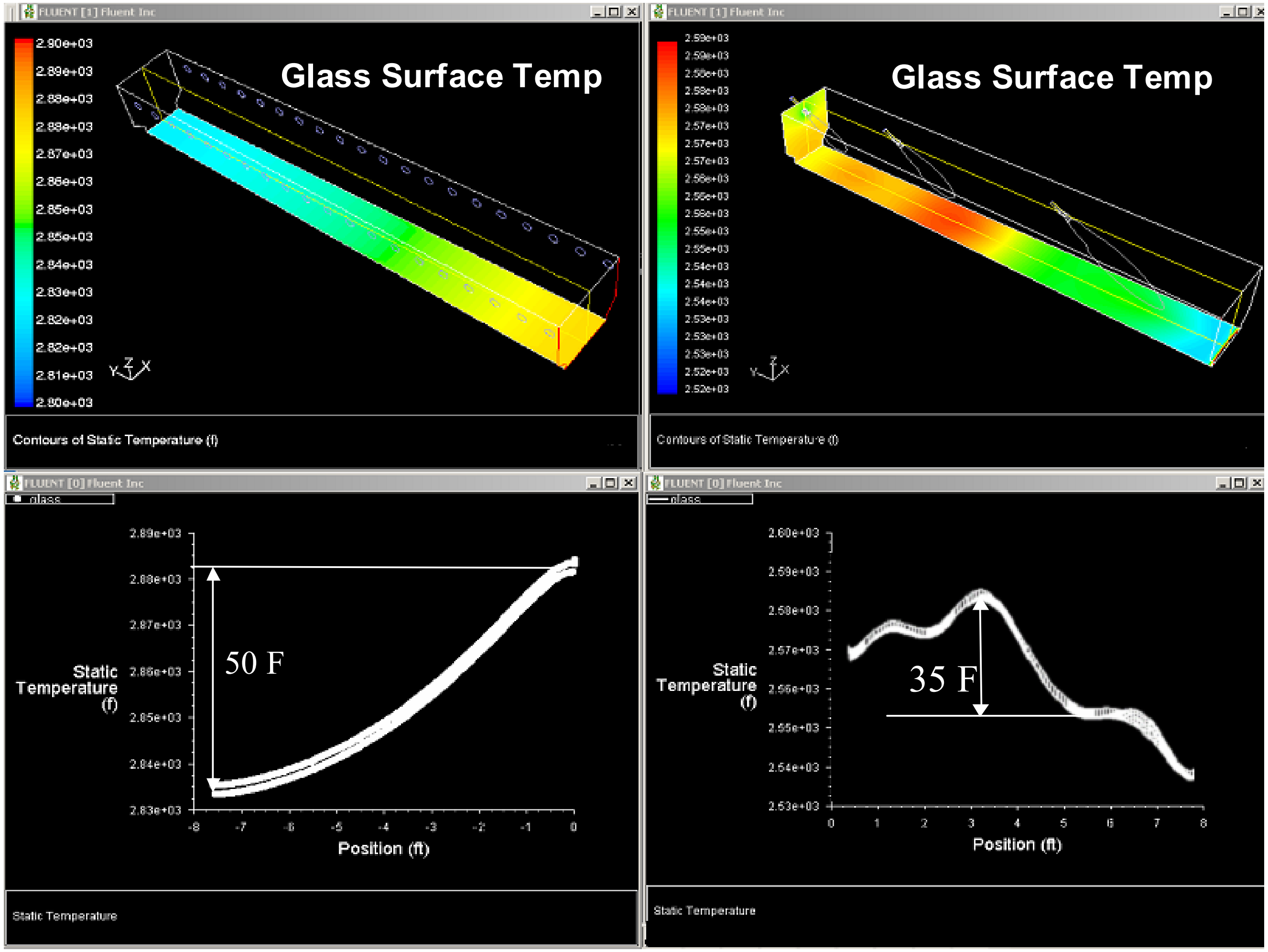


Oxyfuel Technology
Vs.
Conventional System



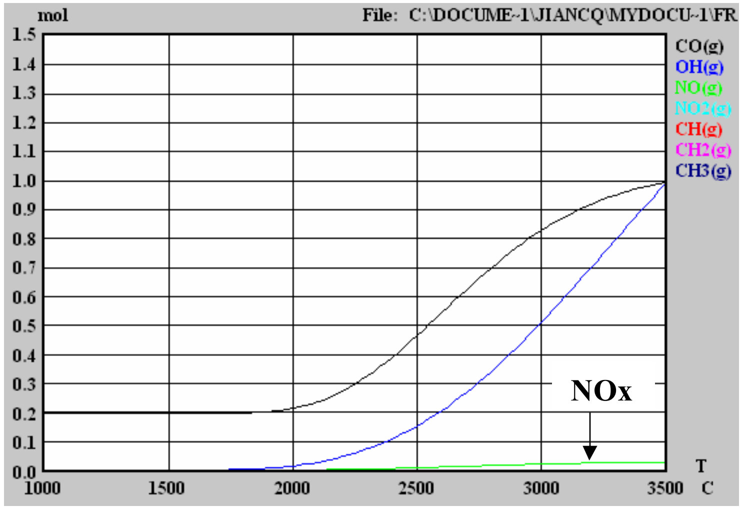


Technical Approach – Temperatures

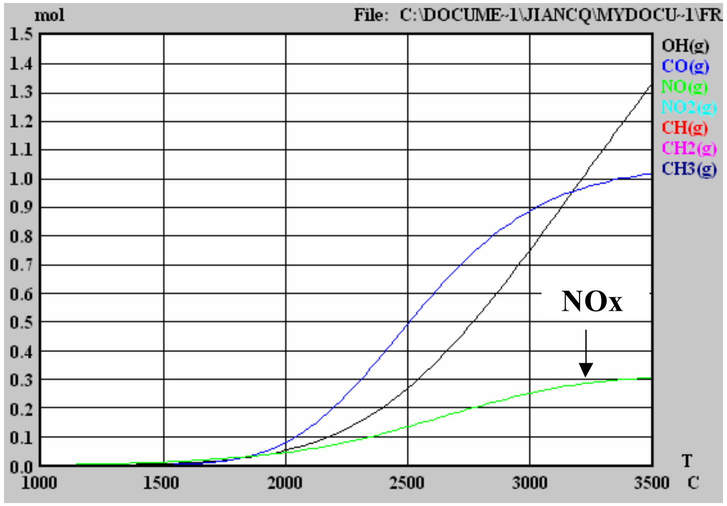


Emissions Reduction

- **Carbon Dioxide Reduction: 65 -70%**
- **Nitrogen Oxides Reduction: 90%**

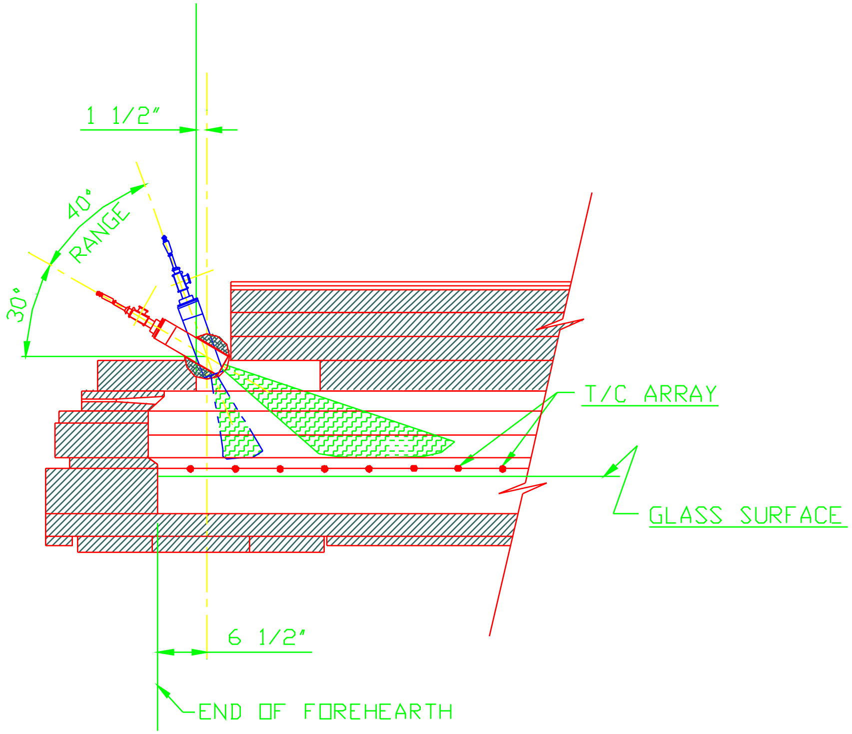


Oxyfuel



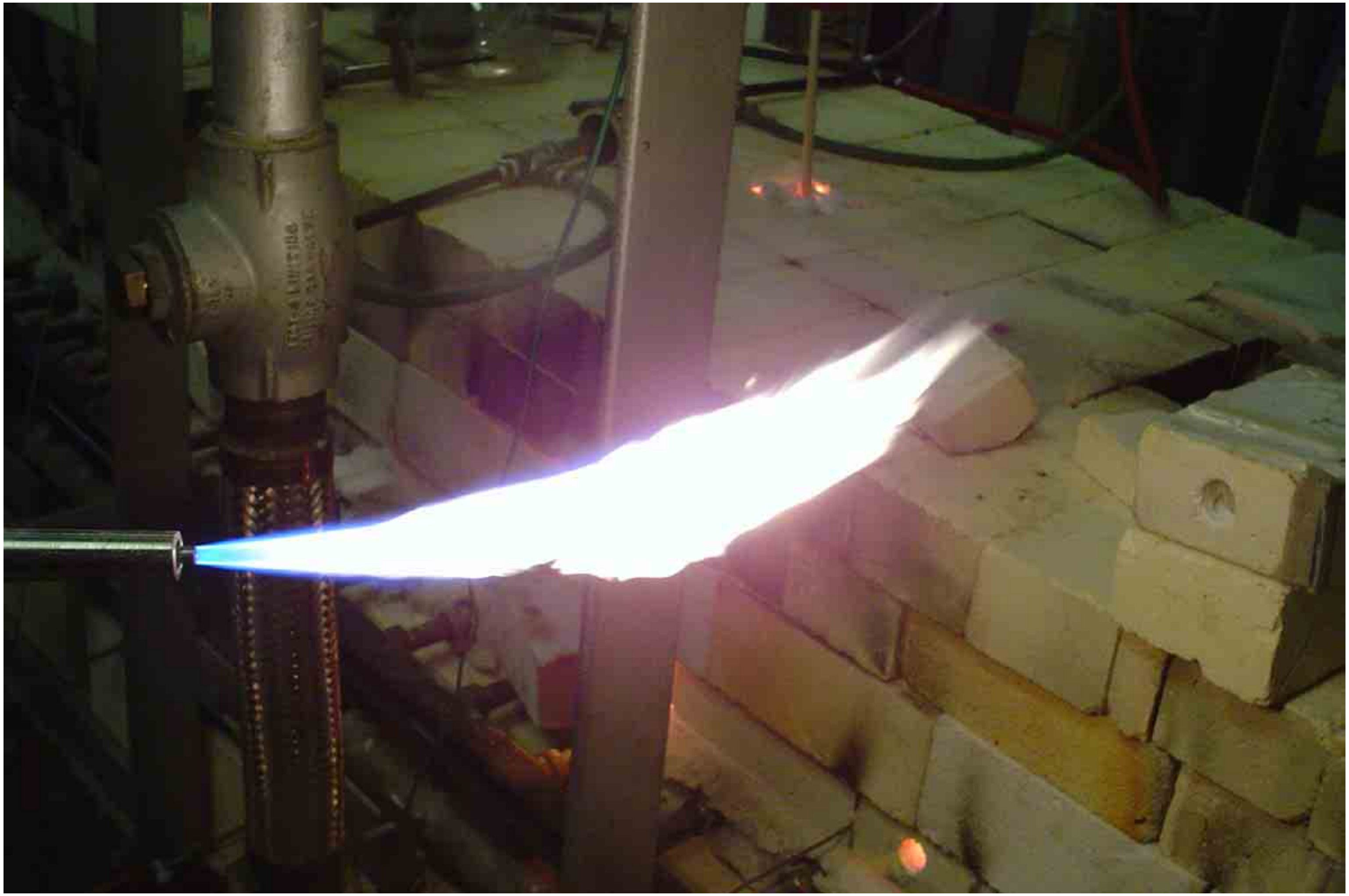
Air/gas

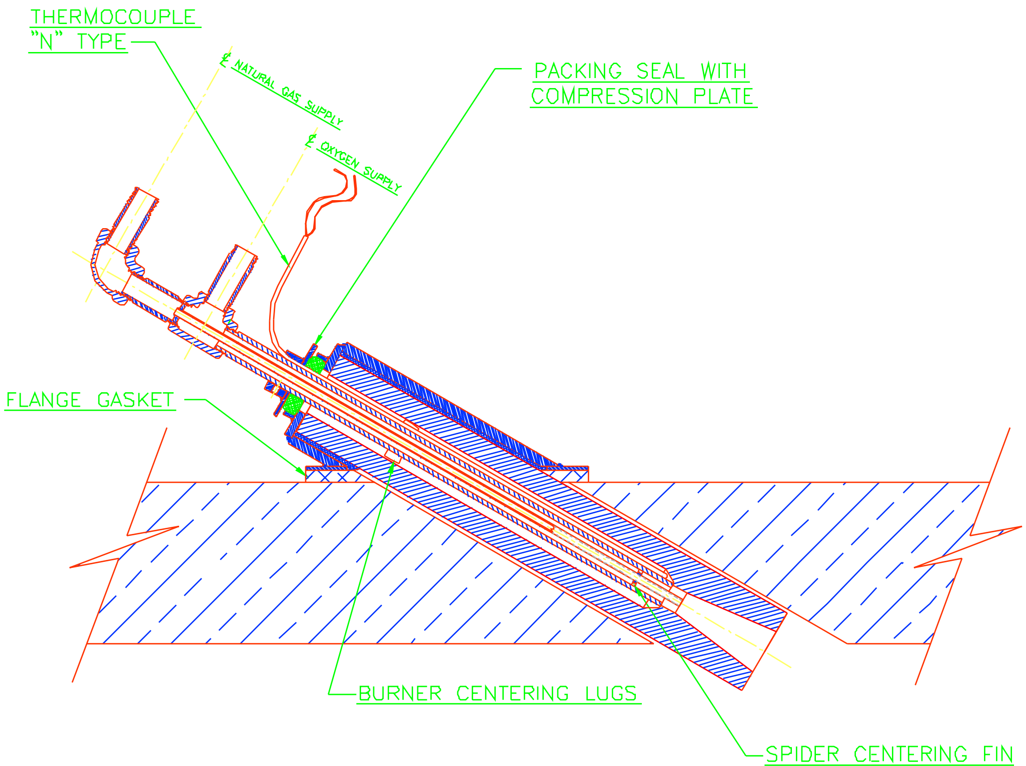
Bench Trials – top fire configuration



SECTION ON ℄ OF FOREHEARTH

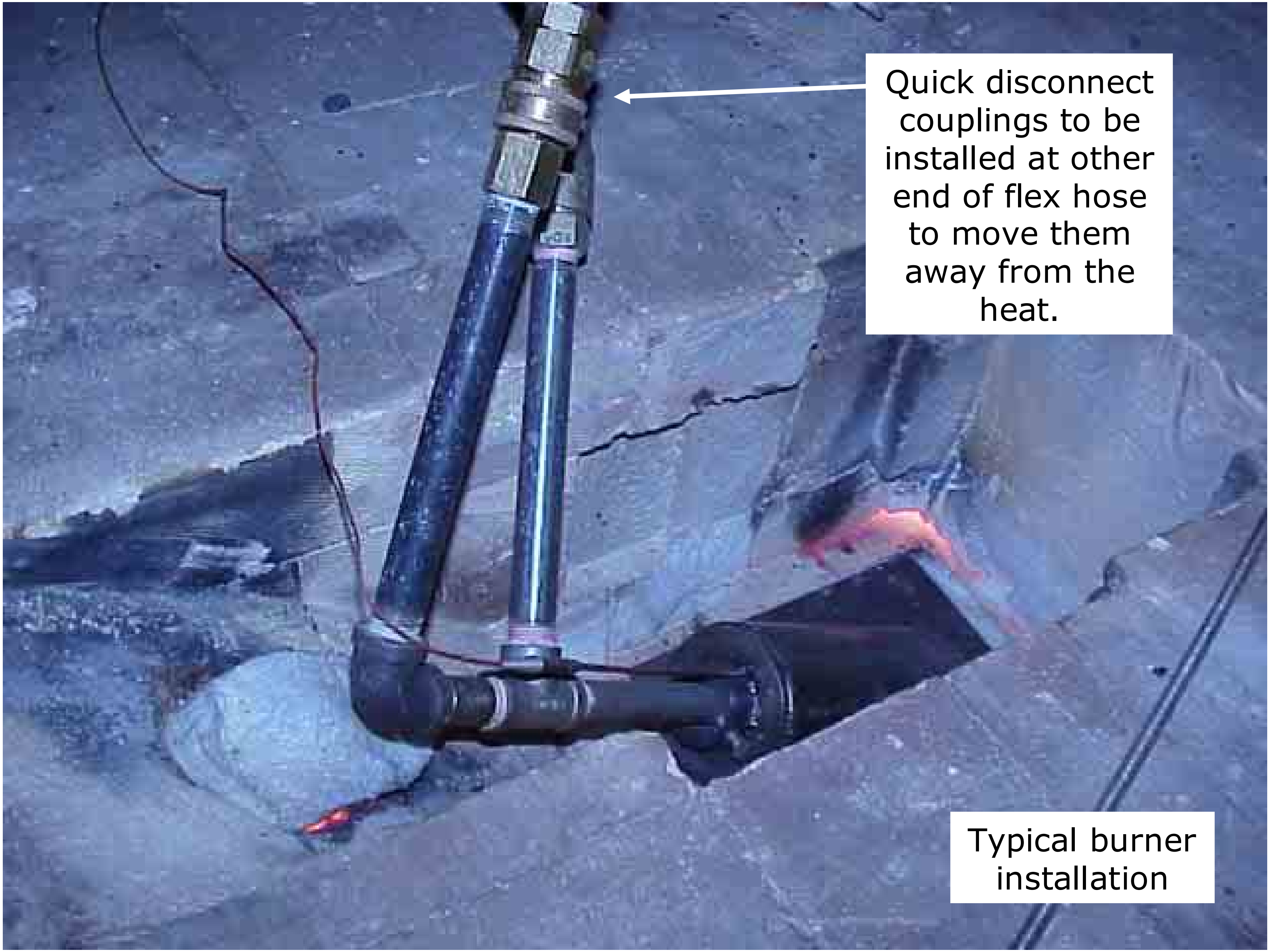
Equal Velocity Burner Trial

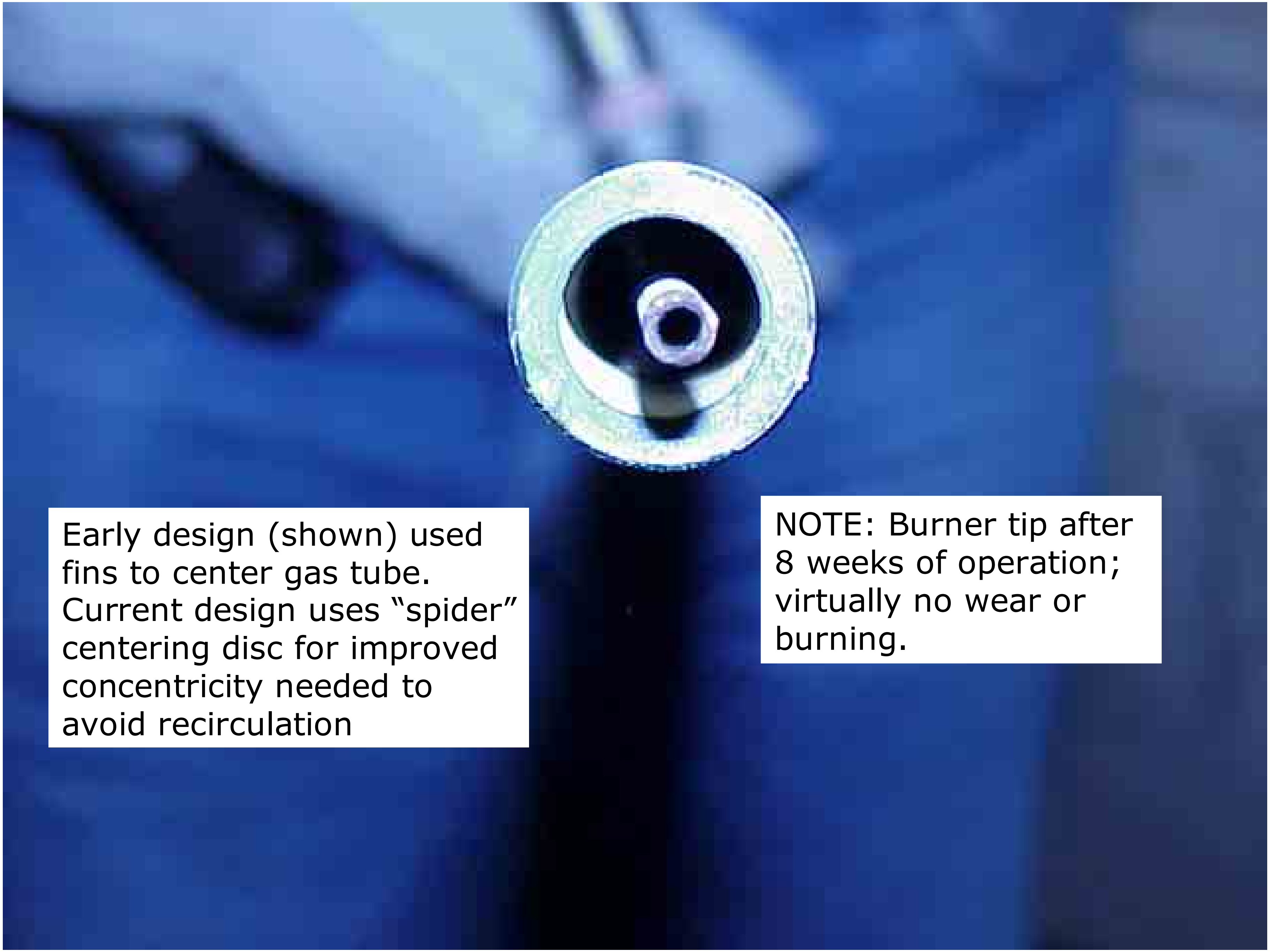




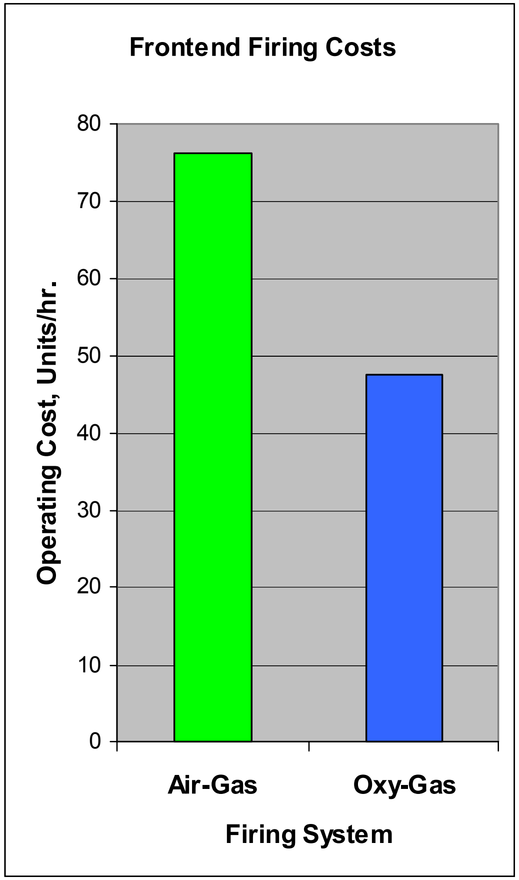
THERMOCOUPLE
"N" TYPE
℄ NATURAL GAS SUPPLY
℄ OXYGEN SUPPLY
PACKING SEAL WITH
COMPRESSION PLATE
FLANGE GASKET
BURNER CENTERING LUGS
SPIDER CENTERING FIN

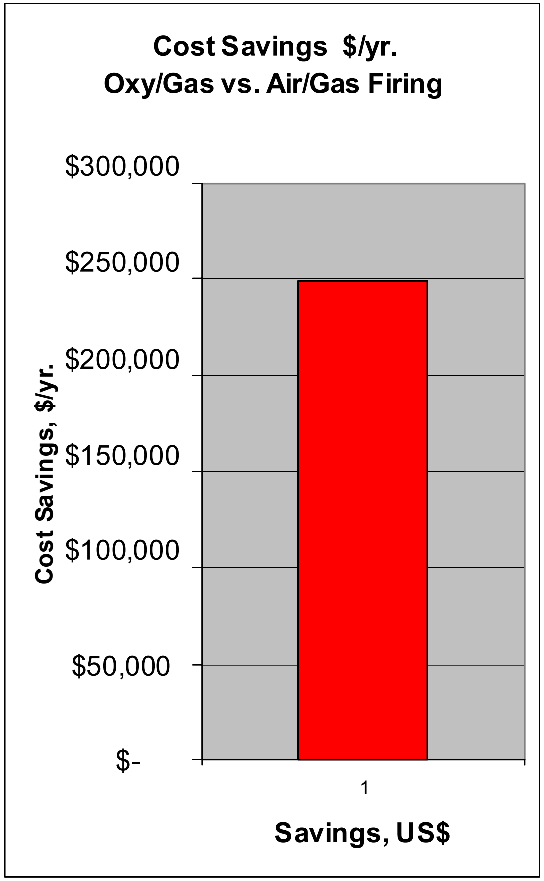
Dave Baker changing out the oxy-gas burner


Quick disconnect couplings to be installed at other end of flex hose to move them away from the heat.
Typical burner installation


Early design (shown) used fins to center gas tube. Current design uses “spider” centering disc for improved concentricity needed to avoid recirculation
NOTE: Burner tip after 8 weeks of operation; virtually no wear or burning.

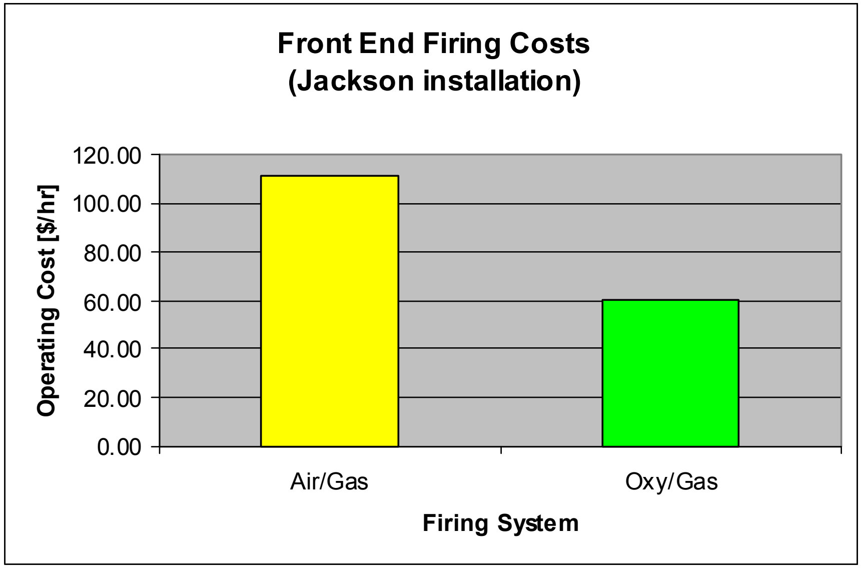
Economics for mid size melter





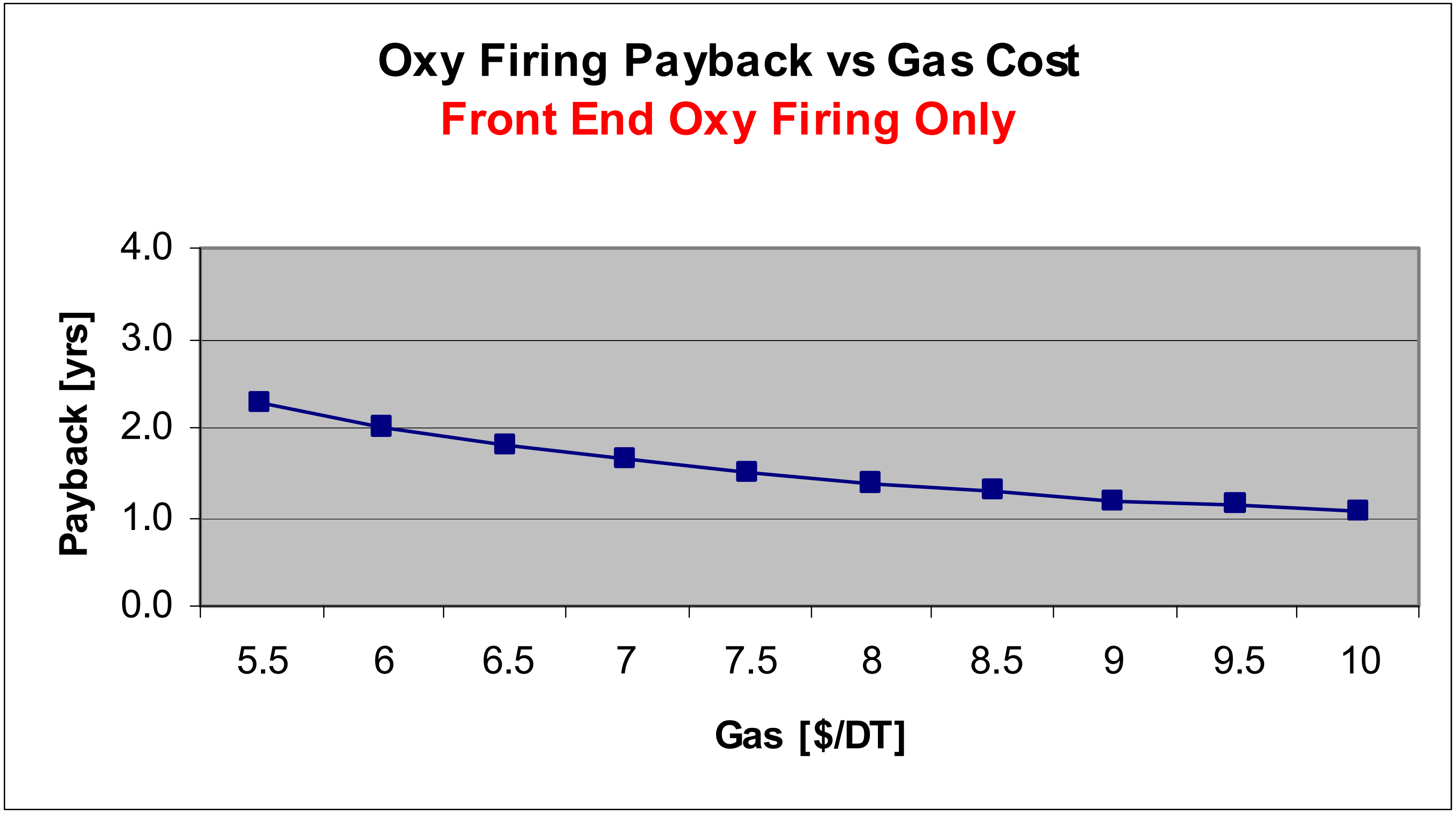
Total Percent Savings w/oxy-gas firing **37**

Economics for Jackson front end



- Gas $6.75/DT
- Energy Input before conversion 16 DT/hr
- Operating Savings $440,000 – 470,000/yr
- Payback (excluding one time R&D development) = 1.85 yrs

Payback vs Gas Cost



Goals – Jackson Installation

- Assessment of equipment improvements for reliability
  - Burner block, check valve, burner packing, manifold design
- Demonstrate "green" melting technology
- Demonstrate cost savings

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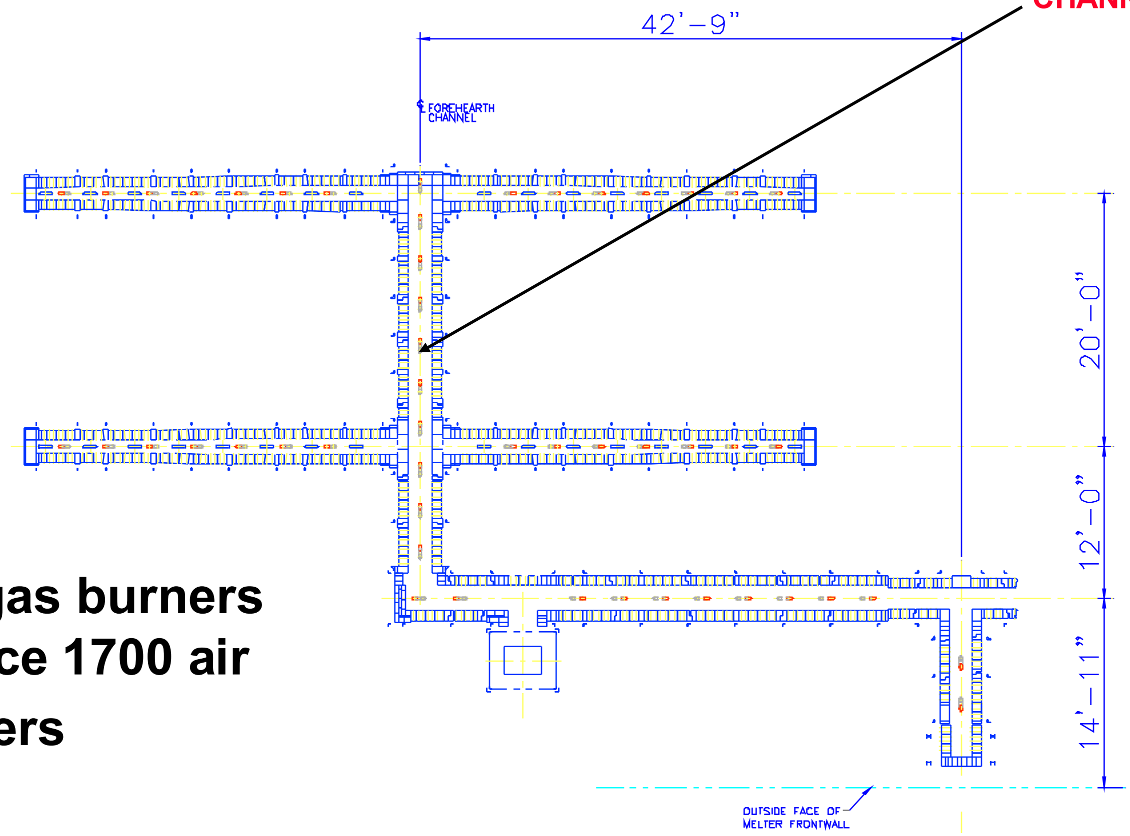
Jackson front end plan view (one half)

TOP FIRE BURNER BLOCK HOLE ON

CENTERLINE OF CHANNEL



108 oxy gas burners will replace 1700 air gas burners

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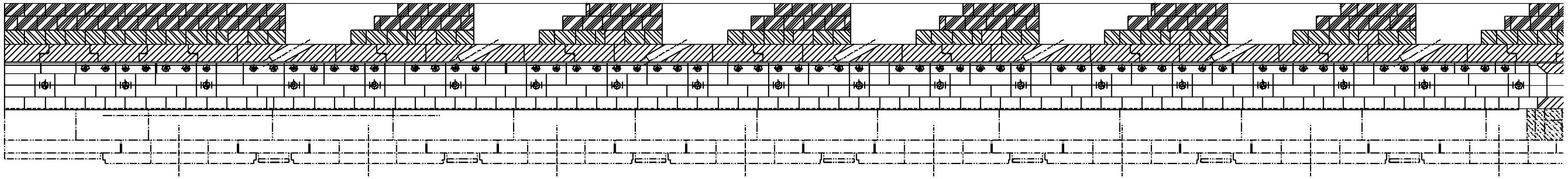
Jackson forehearth: 1 burner, 1 bushing

Profiling:	**potential for improved profiling**
Transmissivity:	**reduced vertical thermal gradient**



Trial Risks – Oxy Fired Burners

- Higher flame temp: risk of melting block
  - 4 top fired burner blocks destroyed in Guelph
    - 1 - fh 7A4: checkvalve, low O2 flow
    - 1 - CFM MC Zone2, #4: trial block design
    - 1 - (CFM MC Zone 2), high temp. oxidation of s/s burner or off ratio flow of gas& O2
    - 1 - CFM MC Zone 2, #5: Feb 18, 04 (cast block material sagging??/gas tube sagging??)
- Degradation of cast (not fired) mullite blocks due to minor melting of burner block bore is a concern in Guelph

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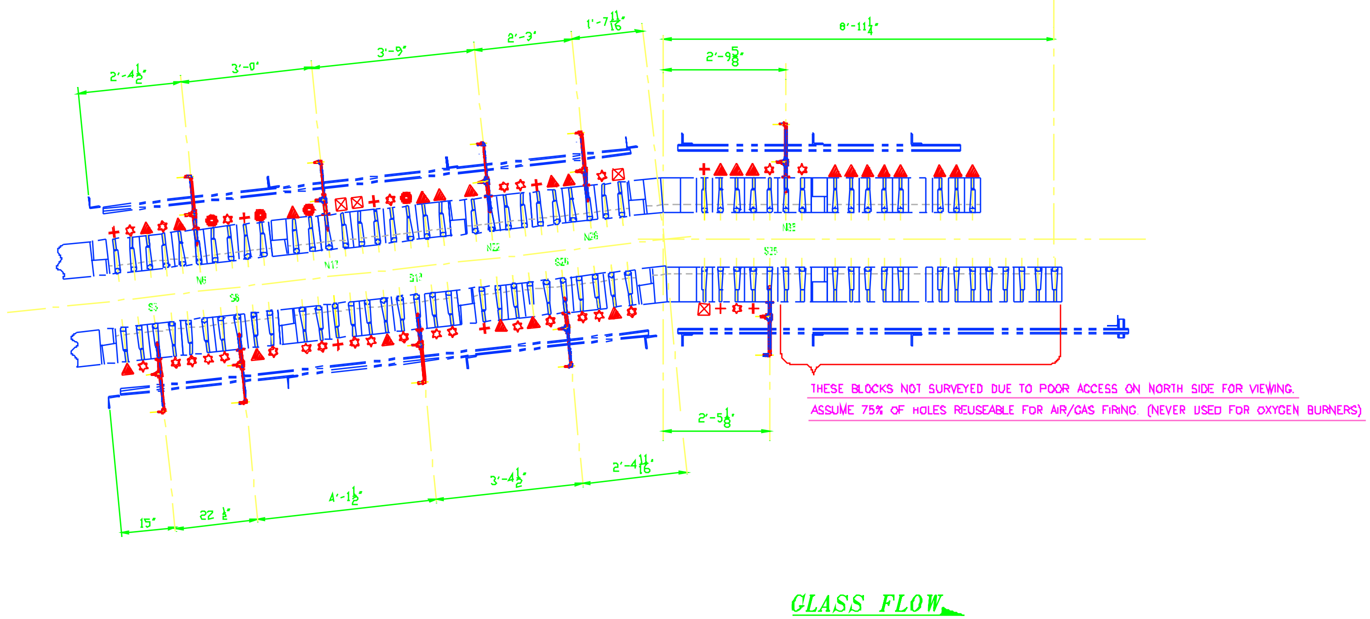
Retrofit Side fire burner and block failures



GUELPH 7A CROSS CHANNEL – ZONE 4 – SIDE FIRED OXYGEN BURNERS
CURRENT CONDITION OF BURNER BLOCKS AS OF 4-23-04

Major constraint:

Using geometry of existing burner blocks

LEGEND

- ● INDICATES CRACKED BLOCK – POSSIBLE FUTURE USE BUT NOT DESIRED
- ✡ INDICATES GOOD CONDITION – SUITABLE FOR FUTURE USE
- ▲ INDICATES POOR CONDITION – NOT SUITABLE FOR FUTURE USE
- + COULD NOT SEE – VIEW OBSCURED BY OPPOSITE BURNER OR STEELWORK
- ⊠ INDICATES BURNER ABANDONED IN PLACE (FUSED TO BLOCK)

Equipment Improvements

- Zone control skid linkage geometry
- Increased size of zone control skid valves
- Increase supply and manifold piping dia.
- Low pressure drop (springless check valve)
- Burner gas tube concentricity (lower gas tube temp)
- Burner material
- Burner block material and internal design

Safety Considerations

Safety Interlocks:

- Minimum temperature for auto ignition
- If oxygen is lost: gas off – per existing safety skid interlocks
- When gas is lost: oxygen for 15 minutes

  O2/N2 mix after 15 minutes

- Check valves upstream of flex hoses

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Consortium activities for Jackson Trial:

CTI/Eclipse: CTI burner in top fired configuration for comparison of two burner technologies

BOC: exhaust gas sampling support

O2/N2 mixing station

Osram: monitoring progress for applicability

Concluding Remarks

- Significant Energy Conservation
- Significant Environmental Benefit (less CO2 & NOx)
- Risks: technology still being developed
  - – months not years of run time: potential for equipment failure due to high temperature flame (burner & block)
  - Impact on fine fiber process is not known

Questions & comments are welcomed!

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- Supplemental Slides follow

Melting Energy Reduction